DISCOVERY

58(314), February, 2022

Status of timber productivity in exotic and indigenous tree plots in Sakhipur areas of Tangail district in Bangladesh

Md. Mijanur Rahman[1]✉, Saleh Ahammad Khan[2], Md. Enamul Kabir[3]

To Cite:
Rahman MM, Khan SA, Kabir ME. Status of timber productivity in exotic and indigenous tree plots in Sakhipur areas of Tangail district in Bangladesh. *Discovery*, 2022, 58(314), 125-133

Author Affiliation:
[1]PhD Researcher, Department of Botany, Jahangirnagar University, Savar, Dhaka, Bangladesh
[2]Professor, Department of Botany, Jahangirnagar University, Savar, Dhaka, Bangladesh
[3]Professor, Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh

✉**Corresponding author:**
Email: md.mijanur@gmail.com

Peer-Review History
Received: 03 December 2021
Reviewed & Revised: 06/December/2021 to 14/January/2022
Accepted: 16 January 2022
Published: February 2022

Peer-Review Model
External peer-review was done through double-blind method.

ABSTRACT

Increasing timber production is vital for growing people to meet their demand for different purposes. Exotic *Acacia auriculiformis* A. Cunn. ex Benth., and *Eucalyptus camaldulensis* Dehnh., were planted instead of indigenous *Shorea robusta* Gaertn., in Sakhipur area for increased timber production. Sakhipur is a pioneer area where huge exotic species, especially *A. auriculiformis*, are planted with the expectation of better and rapid financial benefits. This study was carried out to compare the timber productivity between exotic monoculture of *A. auriculiformis* and *E. camaldulensis* and naturally growing indigenous *S. robusta* and planted *Mangifera indica* L. in order to suggest the type of species suitable among the tree growers to grow. Indigenous *S. robusta* plots showed higher average stem density (2482 per ha), stem volume (321 m^3/ha), and basal area (23 m^2/ha) than that of exotic species plots. But the tree height (10 m) and DBH (13 cm) of *A. auriculiformis* were highest in the area. Stem density across *Acacia*, *Shorea*, *Eucalyptus* and *Mangifera* plots were significantly different. Gross timber production was significantly higher in *Acacia* and *Shorea* plots than *Eucalyptus* and *Mangifera* plots. Local peoples were more interested in planting fast growing exotic species instead of indigenous as it offers quicker financial return. Monoculture of exotic tree species on agricultural land should be discouraged. However, monoculture of exotic tree species can be practiced on degraded, fallow, marginal or specified lands for quicker financial benefits.

Key words: *Acacia*, Basal area, Density, Monoculture, *Shorea*.

1. INTRODUCTION

Bangladesh had been facing an acute shortage of timber and associated produces since the 1970s due to increasing gap between the supply and demand for biomass, fuel and fodder. As the consequence, over exploitation is being executed in government managed forest lands, village woodlots, scrub jungles and homestead forests. In order to bridge the gap between demand and supply of the forest produces, a number of tree plantation projects involving both indigenous and exotic species were launched by the Bangladesh Forest Department and various other local and international development agencies. These projects

DISCOVERY
SCIENTIFIC SOCIETY

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

basically targeted plantations on the available fallow and marginal lands (FAO/UNDP, 1981). Exotic tree species such as *A. auriculiformis* and *E. camaldulensis* were introduced to those plantation programs because of their wide adaptive capacity and faster productivity (De Bell et al., 1985; Ara et al., 1989; Turnbull, 1999; Hossain and Pasha, 2001; Ridenour and Callaway, 2001; Bernhard-Reversat and Loumeto, 2002; Jagger and Pender, 2003; Hossain, 2003; Forrester et al., 2005; Bristow et al., 2006; Erskine et al., 2006; Dogra et al., 2010; Olowoyeye & Ajewole, 2020; Eltahir et al., 2020). Therefore, plantations with exotic tree species are getting more popularity than indigenous tree species now a day in both public and private lands. Local peoples are also interested on such plantations instead of indigenous species plantation because exotic species plantations provide better financial benefit within a short period of time. Afforestation or reforestation programs including block or woodlot plantation with exotic tree species have shown success (Ara et al., 1989; Hossain and Pasha, 2001). Exotic species were showed high yield of timber production, tolerate in degraded sites and resistant to pest and diseases over indigenous species (Davidson, 1995; Forrester et al., 2005). In contrast, some recent studies have depicted possible advantages of indigenous tree species plantation instead of exotic (Hartley, 2002; Lambert et al., 2005; Erskine et al., 2006; Piotto et al., 2010; Neupane & Mandal, 2019). Though there is a debate on plantations of exotic versus indigenous tree species in light of environmental as well as ecological issues. *A. auriculiformis* and *E. camaldulensis* were recommended by the Bangladesh Forest Research Institute (BFRI) as promising tree species for the large scale afforestation and reforestation (Zashimuddin et al., 1983; Davidson and Das, 1985; Latif et al., 1985; Amin et al., 1996; Hossain et al., 1989, 1994, 1996b). GOs and NGOs initiatives were found to improve the tree productivity through providing quality planting materials and technical support to the tree growers (Rahman 1993; Amin et al., 1996; Hocking et al.1997; Das, 2008). Studies on the growth and productivity of *A. auriculformis*, *E. camaldulensis* plantations in Bangladesh described with better biomass yield than indigenous species (Aryal et al., 1999; Kelty, 2006; Hossain and Hoque, 2013; Dutta S and Hossain MK, 2017). However, studies on the said topic in Sakhipur area of Tangail has not been carried out yet. Thus, the objectives of the study were to compare the timber productivity between exotic monoculture of *A. auriculiformis* and *E. camaldulensis* and naturally growing indigenous *S. robusta* and planted *M. indica* in order to suggest the type of species suitable among the tree growers to grow.

2. MATERIALS AND METHODS

Study area

Sakhipur upazila (sub district) occupies an area of 435 km² including 191 km² forest area. Sakhipur is bounded by Ghatail upazila in the north, Bhaluka upazila of Mymensingh district and Sreepur upazila of Gazipur district in the east, Mirzapur upazila and Kaliakair upazila of Gazipur district in the south and Basail and Kalihati upazilas in the west. Sakhipur upazila is consisted of 6 unions, 1 pouroshova, 59 mauza, and 122 villages (BBS, 2012). Sakhipur is situated in 80 km north from Dhaka the capital city of Bangladesh. It is located between 24°11′and 24°26′ N latitudes and between 90°04′ and 90°18′ E longitudes (Figure 1). Sakhipur is a part of Madhupur Sal tract due to which its floristic composition and structure along with wildlife diversity are almost the similar to that of other parts of this forest tract. The Sal forest of Sakhipur is composed of few scattered and degraded patches. *Shorea robusta* is the dominant tree species of Sal forest which represents 70 - 75% trees of the forest and is associated with other tree species (Khan, 1990). In the study area there were a total of 182 plant species of 150 genera of 56 families recorded elsewhere (Rahman *et al.*, 2016).

Climate

Sub-tropical monsoon climate is existed in Sakhipur areas and there are three distinct seasons are existing with, *viz*., summer (March to mid-June), monsoon (mid-June to mid-October) and winter (mid-October to February). Among the climatic factors, rainfall, humidity, sunshine penetration, evaporation and evapo-transpiration, canopy structure etc. affect vegetation growth and development, woodlots and *Shorea* trees as well as the associated undergrowth species to varying extents. The climatic data has been collected from National Water Resource Database (NWRD) of Center for Environmental and Geographic Information Services (CEGIS) and analyzed accordingly. The mean annual rainfall 1937 mm (ranges from 1126 to 2748 mm) and the mean annual temperature 25.86°C (ranges from 20.25°C to 31.48°C). This tropical climate condition is characterized by a distinct rainy season from April to October and a strong dry season from November to March. The relative humidity varies between 69% and 86%, the duration of sunshine ranges from 5-9 hours and average wind speed were 87 km/hour. Average MSL elevation of the area is 19 meter (NWRD/CEGIS, 2015).

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Soil

Sakhipur area belongs to Madhupur Sal (*Shorea robusta*) forest region (Nishat et al. 2002). According to Richards and Hassan (1988), the soils of this area is acidic (moderate to strong). The topography of this area is characterized by plain land or low hills rising 3.0-4.5 m above the surrounding paddy fields, locally known as 'chalas', which are intersected by numerous depressions or 'baids' (Ismail and Miah, 1973). In Sakhipur areas three major types of soil are observed, *viz*., brown mottled terrace soils, deep red brown terrace soils and shallow red brown terrace soil (Richards and Hassan, 1988). About half of the Sal forests land is covered by deep red brown terrace soil. The soils are moderately to strongly acidic in reaction with pH 5.0 - 5.5 (UNDP/FAO, 1988). Major physical problems of soils of this tract are low organic matter content, low fertility and low moisture holding capacity (Alam, 1995). The partly weathered/unweathered Madhupur tract clay is very compact and greatly affects root penetration of crop (Amin et al., 1996).

Selection of research plots

Research plots were selected from Sakhipur area through purposive stratified random sampling. The strategies for selection of research plots were comprised of (i) data of Bangladesh Forest Department on the exotic tree plantation in Madhupur Sal tract, (ii) field reconnaissance survey, (iii) record of previous studies in Madhupur Sal tract, (iii) data on the availability of large plantations of at least one exotic species (e.g. *A. auriculformis*), (iv) consideration of the existence of homogeneous factors and (v) relevance with this study objectives. Based on the diverse ecological habitats, topography, species composition and vegetation cover of the forest areas of Sakhipur, a total of 12 research plots were selected for this study. These 12 research plots were located in Sakhipur both in private and public land composed of three plots of each of *A. auriculiformis*, *S. robusta, E. camaldulensis* and *M. indica*. The size of each research plot was 36 m x 36 m. *A. auriculiformis* plantations occupied the major share and *E. camadulensis* and *S. macrophylla* plantations represented very small share in the study area.

Data collection and analysis

Forest stand tree productivity denotes capacity of the stand to grow trees (m^3/ha/year) and a standard stand should be relatively uniform in species composition or age and managed as a single unit for tree production. The status of tree productivity in each of the *Acacia*, *Eucalyptus*, *Shorea* and *Mangifera* research plots was estimated through calculating the number of trees, density, DBH, height, stem volume and basal area. *Shorea* tree age was estimated through consulting with Forester and local people. Stem diameter at breast height (DBH) more than 5 cm was considered as tree. Every individual tree was identified and recorded accordingly from each sample plot.

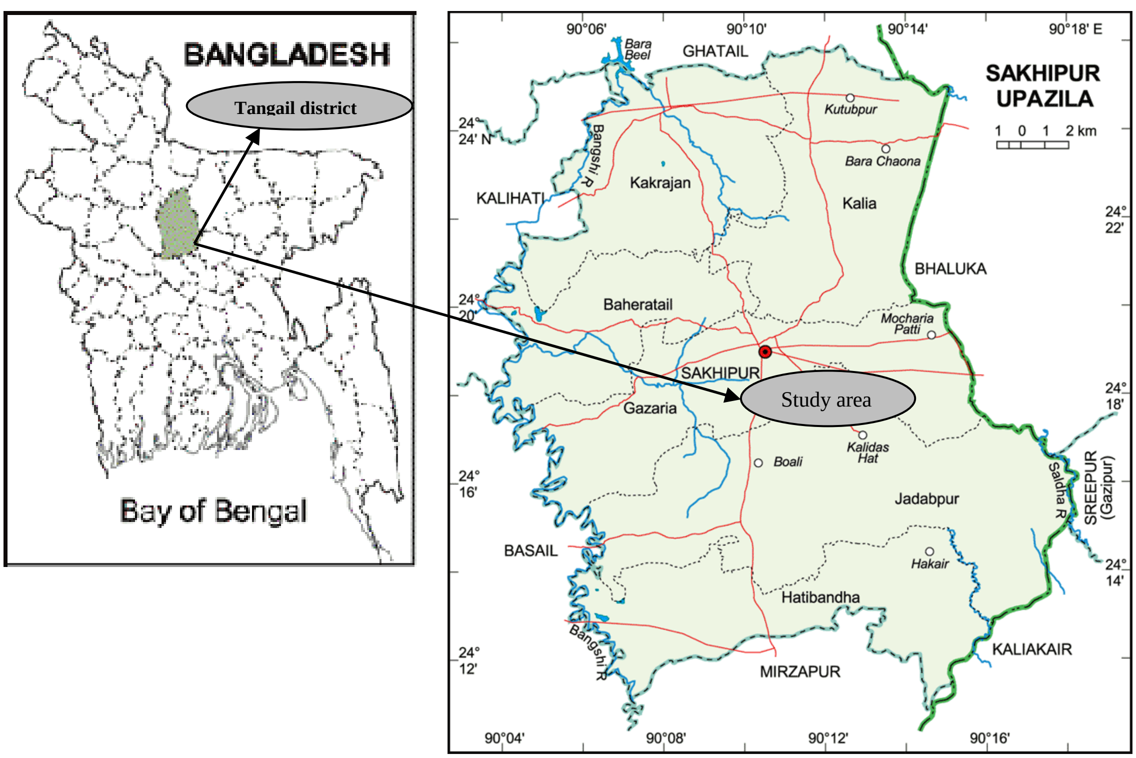

Figure 1. Location of the study area, Sakhipur upazila, Tangail district (Source: Banglapedia)

Diameter of all individual tree was measured from each sample plot using diameter tape. Tree height was measured using range finder in each sample plot. Tree volume was calculated using the diameter and height data. Basal Area per hectare were calculated using the diameter data for each individual tree. One-way ANOVA (DMRT) was used to test for significant differences ($P<0.05$) for marginal means of variables. Besides, data were also managed and analyzed through SPSS and MS office software.

3. RESULTS AND DISCUSSION

Tree density

Tree density in *Acacia* plots ranged between 697 and 1818 ha^{-1}, in *Eucalyptus* plots 515 and 674 ha^{-1}, in *Shorea* plots 1515 and 3477 ha^{-1} and in *Mangifera* plots 424 and 962 ha^{-1}. The average age of the trees ranged between eight to nine years (Table 1).

Table 1. Tree composition of twelve research plots

Plot	Plot name	Plantation year	Average age of trees (years)	Tree density (ha^{-1})
1	*Acacia*	2002	9	697
2	*Acacia*	2003	8	1371
3	*Acacia*	2003	8	1818
4	*Eucalyptus*	2003	8	515
5	*Eucalyptus*	2002	9	606
6	*Eucalyptus*	2002	9	674
7	*Shorea**	-	8 to 9	1515
8	*Shorea**	-	8 to 9	2454
9	*Shorea**	-	8 to 9	3477
10	*Mangifera*	2003	8	424
11	*Mangifera*	2003	8	924
12	*Mangifera*	2003	8	962

* *Shorea* grown up naturally, it is not planted

The highest mean tree density (1626 ha^{-1}) was recorded from indigenous tree plots and the lowest (947 ha^{-1}) from exotic tree plots of ±9 years old plantation. The highest value of average tree density (2482 ha^{-1}) was found in *Shorea* plots followed by *Acacia*, *Mangifera* and *Eucalyptus* plots (1295, 770 and 598 ha^{-1} respectively) (Table 2). Based on the data found on tree density of four types of plots, the following trend can be recognized- *Shorea* > *Acacia* > *Mangifera* > *Eucalyptus* plots. In case of *E. camaldulensis* plots, field observation showed that, illegal felling and lack of proper management resulted in the occurrence of minimum number of trees in contrast to large number of trees in *S. robusta* plots due to natural condition of the habitats. Practically, in this area the double plantation spacing (4 m x 4 m) was maintained in case of edible fruit yielding *M. indica* trees due to which less number of tree stem occurred in *M. indica* plots.

Table 2. Average tree density, height, DBH, basal area and gross tree stem volume in exotic and indigenous plots

Type of plots	Density/ha	Height (m)	DBH (cm)	Basal area (m^2/ha.)	Gross tree stem volume (m^3/ha)
A. Auriculiformis	1295	10	13	16	263
E. camaldulensis	598	9	10	5	109
Exotic plots	947	10	12	11	186
S. robusta	2482	7	11	23	321
M. indica	770	4	9	5	34

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Indigenous plots	1626	6	10	14	178

The data on tree/stem density provided by this study are higher than the records of Das and Sarker (2014) on *S. mahagoni* and *Acacia* plots, Combalicer et al. (2011) on *A. auriculiformis*, Chaturvedi and Raghubanshi (2014) on *S. robusta.* Besides, the data on tree/stem density provided by this study are lower than those reported by Kabir and Webb (2005) on *A. auriculiformis* and *E. camaldulensis*, Islam et al. (2013) on *Acacia,* Tyynela (2001) on *Eucalyptus camaldulensis*, Jalota and Sangha (2000) on *Eucalyptus* and Sapkota et al. (2009) and Rahman (2009) on *S. robusta*. The data of Kumar et al. (2006) on *S. robusta* is consistent with this study. Field observations indicated that, number of trees per ha may vary due to illegal felling, protection level, encroachment, natural disaster (cyclone/storm), site condition, human interference, gap filling through saplings, and removal of undergrowth regeneration etc.

Tree height

The mean tree height recorded for exotic and indigenous tree plots were 10±1 m and 6±2 m respectively in ±9 years old plantation. The highest mean tree height 10±3 m was found in *Acacia* plots, which was followed by 9±3 m, 7±2 m and 4±2 m recorded for *Eucalyptus*, *Shorea* and *Mangifera* plots respectively (Table 2). The data collected on the tree height from four types of plots showed the following sequence- *Acacia* > *Eucalyptus* > *Shorea* > *Mangifera* plots. The data on tree/stem density provided by this study are higher than the records of Bhat et al. (2001) on *A. auriculiformis*, Ali (2009) on *A. auriculiformis* and *E. camaldulensis* Rahman (2009) on *S. robusta.* The data on tree/stem density provided by this study are lower than the records of Das and Sarker (2014) and Combalicer et al. (2011)'s on *A. auriculiformis,* Das and Sarker (2014) on *S. mahagoni,* Kabir and Webb (2005) on *A. auriculiformis* and *E. camaldulensis.* The finding of Islam et al. (2013) on *A. auriculiformis* and Das (2000) on *S. robusta* is consistent to the records of this study. The higher tree height as well as tree growth performance may vary due to age of stand, site suitability, tending operation, site protection measures, undergrowth, micro-climate, soil and edaphic factors.

Tree diameter

The mean tree DBH per tree was calculated as 12±2 cm and 10±1 cm for exotic and indigenous tree plots respectively in ±9 years old plantation. The highest mean DBH 13±2 cm was calculated for *Acacia* plots, followed by 11±2 cm and 10±5 cm for *Shorea* and *Eucalyptus* plots whereas the lowest value 9±3 cm was calculated for *Mangifera* plots (Table 2). The collected data related to the tree DBH of four types of tree plots showed the following sequence- *Acacia*> *Shorea*> *Eucalyptus*> *Mangifera* plots. The data on tree/stem density provided by this study are higher than the records of Bhat et al. (2001) on *A. auriculiformis.* The data on tree/stem density provided by this study are lower than those reported by Ali (2009) on *A. auriculiformis* and *E. camaldulensis and* Islam et al. (2013) on *A. auriculiformis* and Das (2000) on *S. robusta.* The data of Combalicer et al. (2011) on *A. auriculiformis* and Tyynela (2001) on *E. camaldulensis* and Rahman (2009) on *S. robusta* is consistent with this study. The growth performance of trees might be varied due to tending operation, undergrowth vegetation, protection level, age of stand and edaphic factors. With an increase of the DBH the relative abundance of tree decreased in the research plots. The abundance of trees of higher diameter class increased with their wilderness and protection level.

Tree basal area

The mean tree basal area (BA) 14±13 m² and 11±8 m² per ha were calculated respectively for indigenous and exotic tree plots of ±9 years old plantation. The mean basal areas for *Shorea, Acacia, Eucalyptus* and *Mangifera* plots were calculated as 23±3 m², 16±5 m², 5±6 m² and 5±3 m² per ha respectively (Table 2). The data on tree/stem density provided by this study are higher than the records of Chaturvedi and Raghubanshi (2014) and Sapkota et al. (2009) on *S. robusta.* The data on tree/stem density provided by this study are lower than those reported by Das and Sarker (2014) and Combalicer et al. (2011) on *A. auriculiformis* and Kumar et al. (2006), Gupta and Kumar (2014) on *S. robusta.* The data of Tyynela (2001) on *E. camaldulensis* and Rahman (2009) and Sapkota et al. (2009) on *S. robusta* is consistent with this study. Lower tree volume as well as basal area was found in *Eucalyptus* and *Mangifera* plots because plant density of *Eucalyptus* and *Mangifera* in these plots was decreased due to plantation strategies and human disturbances.

Tree stem volume

The average gross tree volume in research plots calculated for exotic and indigenous tree plots were 186±109 cm³ and 178±203 cm³ per ha respectively in ±9 years old plantation. The maximum value of the average gross tree volume 321±25 m³ per ha was recorded from *Shorea* plots and followed by 263±43 m³ per ha and 109±132 m³ per ha were recorded from *Acacia* and *Eucalyptus* plots

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

respectively, whereas the minimum value 34±21 m^3 per ha was recorded from *Mangifera* plots (Table 2). Hence, the data regarding the average gross tree stem volume the selected plots showed the following sequence- *Shorea* > *Acacia* > *Eucalyptus* > *Mangifera* plots. The data on tree/stem density provided by this study are lower than those reported by Jalota and Sangha (2000) and Kabir and Webb (2005) on *E. camaldulensis.* The data of Kabir and Webb (2005) and Islam et al. (2013) on *A. auriculiformis* is consistent with this study.

Variable tree stem volumes per ha in respect to the findings of other studies might be related to the stand age, management system and extent of anthropogenic pressure etc. The additional reasons of finding the minimum number of *Eucalyptus* trees were illegal felling, whereas, less number of tree per plot and less tree stem volume produced per ha in *Mangifera* plots were due to application of the orchard type plantation strategy. Both exotic and indigenous tree species were found capable to survive in the poor or degraded site conditions and to perform production of satisfactory amount of tree volume as well as tree biomass production. However, *Shorea* trees produced highest stem volume followed by *Acacia* and others. The tree density, stem volume and basal area coverage in indigenous tree plots were found comparatively higher than those of exotic tree plots due to less human interference, less illegal felling and conservation management initiatives. Stand productivity, i.e. tree basal area is nevertheless highly correlated with tree volume and biomass and is used as the measure of plantation productivity widely. In the indigenous tree plots, the *Shorea* plots were comparatively higher in stem density, stem volume, basal area coverage than the exotic species plots that might be due to the natural condition of the habitats and relatively less anthropogenic pressure. In the exotic tree plots, stem density, volume and basal area coverage decreased due to human interference, cattle grazing, illegal felling, lack of technical knowledge and inadequate care etc. and this finding is supported by Das (2008). The wood production varies due to different status of education, awareness, soil fertility, fertilizer application, quality planting material, protection or fencing, irrigation, pruning, thinning, gap filling, plantation technique and management (Kabir and Webb, 2005 and Ali, 2009). According to the views of the respondents, plot tree coverage and productivity were decreased due to over-exploitation, branch cutting, illicit cutting of trees, poor protection, fuel wood and leaf collection, soil erosion, poor silvicultural management (tending operation), land use changes, encroachment etc.

4. CONCLUSION

In Sakhipur area, the mass people were reported getting notable financial benefits within ±10 years through cultivating the fast growing exotic tree species. The tree growers favored the planting of exotic tree species because of wide adaptability of the species, well and fast growing, and both in dry and moist lands. In this relation, the tree growers of the study area were planting a lot of fast growing exotic tree species there in comparison to indigenous. However, the trees of a single species *A. auriculiformis* occupied the major percentage of plantation in village forest and farmlands and those of *E. camadulensis* and *S. macrophylla* constituted the poor percentage. The government strategies and policies on the massive plantation of exotic species for timber and fuel wood production need to be reviewed based on ecological and socio-economic insights. Besides monoculture, experiments on mixed tree cropping for timber production with short rotation of agroforestry products such as nuts, fruits, honey, herbs, firewood should be conducted.

Acknowledgments

The authors thank the Bangladesh Forest Department for granting permission to work in the forest of Tangail forest division. It is my greatest pleasure to express my heartiest gratitude and profound thanks to my supervisors Dr. Saleh Ahammad Khan, Professor, Department of Botany, JU, Savar, Dhaka, Bangladesh for their overall supervision. Thanks are also due to Professor Dr. Md. Enamul Kabir, Forestry and Wood Technology Discipline, Khulna University for cordial helps and discussions.

Authors' Contributions

All authors contributed equally.

Funding

This study has not received any external funding.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Alam, M.K. 1995. Diversity in the Woody Flora of Sal Forests of Bangladesh. Bangladesh Journal of Forest Science. 24:41-52.
2. Ali, Q.L. 2009. Socio-economic impact and lesson learned from the management of social forestry programme implemented by government and nongovernment organizations in Bangladesh. PhD Thesis. Department of Botany, Jahangirnagar University, Savar, Dhaka, Bangladesh.
3. Amin, S.M.R., Ahmed, F.U. and Fattah, I.M. 1996. Social forestry in Bangladesh: Concept and present status. *In* : Agroforestry in Bangladesh. M. A. Haque (ed.). VFFP, SDC, Dhaka and BAU, Mymensingh, pp. 30-37
4. Ara, S., Gafur, M.A. and Islam, K.R. 1989. Growth and biomass production performance of *Acacia auriculiformis* and *Eucalyptus camaldulensis* reforested in the denuded hilly lands. *Bangladesh J. Bot*. 18(2):187-195.
5. Aryal, U.K., Hossain, M.K., Koirala, B., Mridha, M.A.U., Xu, H.L. and Umemura, H. 1999. Effects of pure and mixed planting of *Eucalyptus camaldulensis* Dehnh. and *Albizia procera* (Roxb.) Benth on Growth, Biomass Yield and Soil Fertility. Nature Farming and Sustainable Environment II: 57-62.
6. BBS. 2012. Community Report, Tangail Zila, Population and Housing Census-2011, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning.
7. Bernhard-Reversat, F. and Loumeto, J.J. 2002. The litter system in African forest-tree plantations. In: V. M. Reddy (Ed.), Management of Tropical Plantation-forests and Their Soil-litter System, Science Publishers Inc., Enfield, New Hampshire, U.S.A., 11-39.
8. Bhat, D.M., Murali, K.S. and Ravindranath, N.H. 2001. Formation and recovery of secondary forests in India: a particular reference to Western Ghats in southern India. Journal of Tropical Forest Sciences. 13(4):601-20.
9. Bristow, M., Vanclay, J.K., Brooks, L. and Hunt, M. 2006. Growth and species interactions of *Eucalyptus pellita* in a mixed and monoculture plantation in the humid tropics of north Queensland. Forest Ecology and Management. 233:285-294.
10. Chaturvedi, R.K. and Raghubanshi, A.S. 2014. Assessment of carbon density and accumulation in mono- and multi-specific stands in Teak and Sal forests of a tropical dry region in India. Forest Ecology and Management. 339:11-21.
11. Combalicer, M.S., Lee, D.K., Woo, S.Y., Park, P.S. and Lee, K.W. 2011. Above ground biomass and productivity of nitrogen-fixing tree species in the Philippines. Scientific Research and Essays. 6(27):5820-5836.
12. Das, M.K. 2000. Natural Sal forest protection by villagers' groups in Central Bangladesh. Grassroots Voice: A Journal of Indigenous Knowledge & Development. 3(3):119-121.
13. Das, M.K. 2008. Proshika: Marginalized peoples' participation in Bangladesh. *International Journal of Social Forestry*. 1(2):184-193.
14. Das, N. and Sarker, S.K. 2014. Tree species diversity and productivity relationship in the central region of Bangladesh. Journal of Forests. 1(3):47-56.
15. Davidson, J. 1995. Ecological aspects of *Eucalyptus* plantations. Proceedings of the Regional Expert Consultation on *Eucalyptus*, 4-8 October, 1993, vol. 1, RAPA publication: 1995/6. FAO Regional Office for Asia and the Pacific, Bangkok, 35-72.
16. Davidson, J. and Das, S. 1985. Eucalypts in Bangladesh-A review. Bangladesh Forest Research Institute, Chittagong, Bangladesh. 246.
17. De Bell, D.S., Whitesell, C.D. and Schubert, T.H. 1985. Mixed Plantations of *Eucalyptus* and Leguminous Trees Enhance Biomass Production. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Paper PSW-175.
18. Dogra, K.S., Sood, S.K., Dobha, P.K. and Sharma, S. 2010. Alien plant invasive and their impact on indigenous species at a global scale: a review. J. Ecol. Nat. Environ. 2(9):175-186.
19. Dutta, S. and Hossain, M.K. 2017. Effects of Mixed Plantation on Growth and Biomass Yield of Two Common Plantation Trees of Bangladesh. Journal of Forest and Environmental Science.Vol. 33 (1):22-32. doi.org/10.7747/JFES.2017.33.1.22
20. Eltahir MES, Ismaeil EM. Growth Attributes as Characteristics of High Gum Yield *Hashab* Trees (*Acacia senegal* L.) in *Shikan* Locality, North Kordofan, Sudan. Species, 2020, 21(68), 238-243
21. Erskine, P.D., Lamb, D and Bristow, M. 2006. Tree species diversity and ecosystem function: can tropical multi-species plantations generate greater productivity? Forest Ecology and Management. 233:205-210.
22. FAO/UNDP. 1981. Tropical Forest resources assessment project, Rome, Italy.
23. Forrester DI, Bauhus H, Cowie AL (2005). On the success and failure of mixed species tree plantations: lessons learned from a model system of *Eucalyptus globulus* and *Acacia mearnsii*. Forest Ecology and Management. 209:147-155.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

24. Gupta, S.R. and Kumar, R. 2014. Vegetation composition and plant biodiversity in forest ecosystems of Siwaliks in northern Haryana. Indian Journal of Fundamental and Applied Life Sciences. 4(2): 76-88.
25. Hartley, M.J. 2002. Rationale and methods for conserving biodiversity in plantation forests. Forest Ecology and Management. 155: 81-95.
26. Hocking, D., Hocking, A. and Ray, I. 1997. Trees in Bangladesh paddy fields and homesteads: the future of forestry in crowded countries, *Commonwealth Forestry Review.* 76(4):255-260.
27. Hossain, M.K. 2003. Growth Performance and Critics of Exotics in the Plantation Forestry of Bangladesh. Institute of Forestry and Environmental Sciences, Chittagong University, Chittagong-4331, Bangladesh.
28. Hossain, M.K. and Hoque, A.T.M.R. 2013. Eucalyptus dilemma in Bangladesh. Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, pp 148.
29. Hossain, M.K. and Pasha, M.K. 2001. Alien Invasive Plants in Bangladesh and their Impacts on the Ecosystem. In: Assessment and Management of Alien Species that Threatened Ecosystem, Habitats and Species. Secretariat of the Convention on Biological Diversity, CBD Technical Paper No. 21, Montreal, Canada, 73-75.
30. Hossain, M.K., Islam, Q.N., Islam, S.A., Tarafdar, M.A., Zashimuddin, M. and Ahmed, M. 1989. Assistance to the Second Agricultural Research Project, Bangladesh. Status Report on the Activities of the Silvicultural Research Division, BFRI, FAO, Chittagong. 20.
31. Hossain, M.K., Sarker, S. and Kamaluddin, M. 1996b. Initial growth performance of *Eucalyptus* species and provenances at Chittagong University Campus. Chittagong Univ. Stud., part II, Science. 20(1):129-131.
32. Hossain, M.K., Zashimuddin, M., Islam, S.A., Tarafdar, M.A. and Islam, Q.N. 1994. Growth and yield of coppice crops of three *Eucalyptus* species in the Sal forests of Bangladesh. Bangladesh J. For. Sci. 23(2):61-66.
33. Islam, S.S., Islam, M.S., Hossain, M.A.T. and Alam, Z. 2013. Optimal Rotation Interval of Akashmoni (*Acacia auriculiformis*) Plantations in Bangladesh. Kasetsart J. (Soc. Sci) 34:181-190.
34. Ismail, M. and Miah, M.M. 1973. Studies on some deciduous Sal forests of Bangladesh. In: Ismail, M. (Ed.), Ecology of Bangladesh Vegetation 2. Botanical Survey of Bangladesh, Department of Botany, University of Dhaka, Bangladesh.165-187.
35. Jagger, P. and Pender, J. 2003. The role of trees for sustainable management of less-favored lands: the case of *Eucalyptus* in Ethiopia. Forest Policy and Economics. 5(1):83-95.
36. Jalota, R.K. and Sangha, K.K. 2000. Comparative ecological-economic analysis of growth performance of exotic *Eucalyptus tereticornis* and indigenous *Dalbergia sissoo* in monoculture plantations. In Ecological Economics. 33:487–495.
37. Kabir, M.E. and Webb, E.L. 2005. Productivity and suitability analysis of social forestry woodlot species in Dhaka Forest Division, Bangladesh. Forest Ecology and Management. 212:243-252.
38. Kelty, M.J. 2006. The role of species mixtures in plantation forestry. Forest Ecol Manag 233: 195-204.
39. Khan, M.S. 1990. Towards sustainable development: Genetic Resources in Bangladesh. International Union for Conservation of Nature and Natural Resources. World Conservation Union. National Conserve. Strat. Bangladesh Agril. Res. Council, Dhaka.
40. Kumar, A., Marcot, B.G. and Saxena, A. 2006. Tree species diversity and distribution patterns in tropical forests of Garo Hills in India. Current Science. 91(10):1370-1381.
41. Lambert, M.C., Ung, C.H. and Raulier, F. 2005. Canadian national tree above ground biomass equations. Can. J. For. Res. 35:1996-2018.
42. Latif, M.A., Khan, S.A. and Kamaluddin, M. 1985. Prospects of *Acacia mangium* for afforestation in Bangladesh. Pakistan J. For. 35(1):7-12.
43. Neupane S, Mandal RA. Economic analysis of community forests in Terai, Nepal. Discovery, 2019, 55(286), 531-539
44. Nishat, A., Huq, S.M.I., Barua, S.P., Reza, A.H.M.A. and Khan, A.S.M. 2002. Bio-ecological Zones of Bangladesh. The World Conservation Union (IUCN), Dhaka, Bangladesh. 25, 54-55.
45. NWRD/CEGIS. 2015. National Water Resources Database /Center for Environment and Geographic Information Services. CEGIS is a public trust under the Ministry of Water Resources, Dhaka-1212, Bangladesh.
46. Olowoyeye T, Ajewole O. Factor and Revenue Analysis of Small Scale Palm oil Processing in Ekiti state, Nigeria. Discovery, 2020, 56(295), 381-387
47. Piotto, D., Craven, D., Montagnini, F. and Alice, F. 2010. Silvicultural and economic aspects of pure and mixed native tree species plantations on degraded pasture-lands in humid Costa Rica. New Forests. 39:369–385.
48. Rahman, M.M. 1993. Social forestry programme of Proshika (MUK). In T.B.S. Mahat, ed. *NGOs and participatory forestry in Bangladesh*. Proceedings of the workshop held at the BARC on 16 April 1992. Dhaka, Bangladesh, BARC-Winrock International.
49. Rahman, M.M. 2009. Plant diversity and anthropogenic disturbances in the Sal (*Shorea robusta* Gaertn.) forests of Bangladesh. PhD Thesis, Institute of Silviculture, Department of Forest and Soil Sciences, University of

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Natural Resources and Applied Life Sciences, Vienna, Austria. 7-30.

50. Rahman, M.M., Khan, S.A,, Hossain, G.M. and Rahim, M.A. 2016. Undergrowth species composition of the exotic and indigenous tree plots in deciduous forest area of Hoteya forest range of Tangail district, Bangladesh. American Journal of Plant Biology. 1(1): 1-12. doi: 10.11648/j. ajpb.20160101.11
51. Richards, B.N. and Hassan, M.M. 1988. A coordinated forest soils research programme for Bangladesh. Working Paper No.4, Second Agricultural Research Project (Forestry Sector), UNDP/FAO Project BGD/83/010.
52. Ridenour, W.M. and Callaway, R.M. 2001. The relative importance of allelopathy in interference: the effects of an invasive weed on a native bunchgrass. Oecologia. 126(3):444-450.
53. Sapkota, I.P., Tigabu, M. and Odén, P.C. 2009. Species diversity and regeneration of old-growth seasonally dry *Shorea robusta* forests following gap formation in Nepal. J. For. Res. 20(1):7-14.
54. Turnbull, J.W. 1999. Eucalypt plantations. New Forest. 17:37-52.
55. Tyynela, T.M. 2001. Species diversity in *Eucalyptus camaldulensis* woodlots and miombo woodland in Northeastern Zimbabwe. New Forests. 22:239-257.
56. UNDP/FAO. 1988. Land resources appraisal of Bangladesh for agricultural development. Report to Agro-ecological regions of Bangladesh. UNDP/FAO project BGD/81/035 Technical Report 2. 570.
57. Zashimuddin, M., Latif, M.A., Khan, S.A. and Davidson, J. 1983. Performance of different provenances of *Acacia mangium* in Bangladesh. Bano Biggyan Patrika. 12(1&2):57-61.